5.10 GRADUATE FIELD TRAINING IN ATMOSPHERIC MEASUREMENTS

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1. A MULTI-OBJECTIVE RESEARCH CLASS

Advancement in atmospheric research relies on the technological capability and creativity of scientists, yet there are few degree programs in the atmospheric sciences that offer a formal course in research methods and project design (Takle, 2000). Observational research technology has been a focus of graduate training in the Atmospheric Sciences degree program at the University of Nevada, Reno (UNR), with several field courses utilizing DRI, NCAR and NSF facilities (Hallett, 1990; Hallett *et al.,* 1993).

This paper describes a field-oriented course that brings together graduate students from different degree disciplines to benefit from three primary objectives: (1) provide a structured course in which to teach the complete process of conducting a research project, (2) allow graduate students to study in a collaborative team environment where they gain new knowledge on atmospheric research instrumentation, and (3) promote interdisciplinary research related to mountain meteorology.

2. THE FIELD RESEARCH PROCESS: DESIGN AND CONQUER

The optimal method for teaching a new concept or technique is active involvement of students with the instructor and each other. Our graduate-level course focusing on field research is therefore structured to include the complete process of a field study as it typically occurs for funded research programs. The necessity of adequate prior planning and end-to-end project design is stressed. The course begins during the Fall semester with meetings between the instructors and students. The research interests of the students are discussed in the context of mountain meteorological processes.

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The study location is the Desert Research Institute (DRI) Storm Peak Laboratory (Borys and Wetzel, 1997), a high-altitude research and teaching facility in the Rocky Mountain region of northern Colorado (Figure 1).

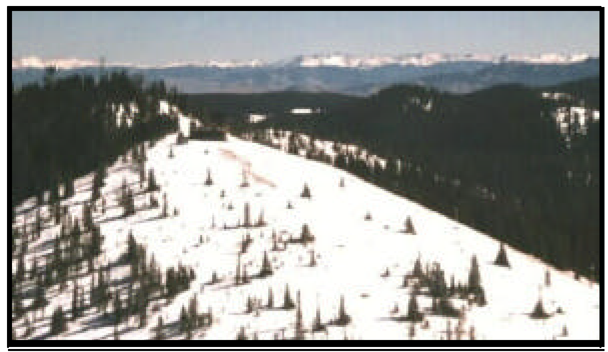

Fig. 1. Ridge-top location of the DRI Storm Peak Laboratory (SPL) research and teaching facility in northwestern Colorado. SPL is on the open peak in the foreground and photo is looking northeast.

Each student writes a proposal for their intended study, following the NSF proposal format. The project description must include sections on scientific goals and previous work related to the study, research methods and instrumentation to be used, logistical and cost summaries, expected outcomes, the relationship of the planned research to broader applications, and references. Proposals are reviewed by the instructors, who give advice and suggestions to ensure that the objectives and techniques are feasible within the limitations of the field project time schedule, expected meteorological conditions and available facilities.

The field component of the class takes place during the Winter break between semesters. The students are responsible for all planning of instrument transport and personnel travel for the field session of two-week duration. After arrival at the field site, the instrument setup, calibration and operational checks are performed in the first day or two, to be ready for desired meteorological conditions as soon as they occur. Each student is assigned to a rotating schedule of weather forecasts and summaries, which they prepare using access weather forecast and nowcast information through a wireless Internet and on-site computer systems, and take into account the various observational needs of the various projects.

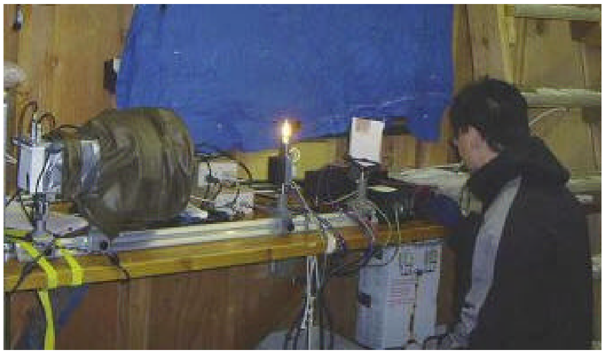

Fig. 2. Atmospheric Sciences graduate student Dong-Chul Kim calibrating a UV actinic flux sensor prior to field deployment.

Fig. 3. Hydrologic Sciences graduate student Katrina Smolen working with tower instrumentation system for characterizing the radiative energy budget of an open snowfield.

Group meetings are scheduled for each evening, offering the opportunity to make adjustments in the plans for the upcoming 24-hour period based on the forecaster's briefing, to discuss and resolve instrument problems, and to find out who needs help with their field logistics or scientific quandaries. A short update to the weather forecast is also made each morning.

The various research projects are diverse in their time of activity, some taking observations only during precipitation, some only during clear air, or at night while the Lab is above the inversion, or only during daylight and cloud-free conditions for solar flux studies. This situation teaches the value of contingency planning and adaptability in their design of field projects.

3. "OBSERVATIONS" vs. "MEASUREMENTS"

In many cases, research scientists use measurements obtained from remote networks or previously collected databases, and observation techniques far from their experience. Hands-on familiarity with the limitations of instrument technology and the vagaries of measurement methodology is extremely valuable in later research, so the course activities establish a team setting in which the students collaborate on implementing a wide variety of research tools.

Storm Peak Laboratory (SPL) supports ongoing monitoring instrumentation for mountain climate and weather parameters (temperature, humidity, wind, pressure, solar irradiance), ambient ozone concentrations, CN and ultrafine aerosol concentrations, aerosol complete size distributions, and multispectral UV, visible and near-infrared irradiances with derived ozone column amounts and aerosol optical depths.

Additional equipment includes cloud microphysics probes for measurement of droplet size distributions and liquid water contents, a 2-D optical array probe for recording images and size distributions of ice crystals, a high-resolution balance gage for snow mass flux measurements, mass displacement rain/snow gages, and a remote control snow spectrometer for video recording and mass calculation for individual precipitating crystals.

Fig. 4. Atmospheric Sciences graduate student Lynn Rinehart and Dr. Douglas Lowenthal constructing cloud sampling apparatus for study of organic contaminants in cloud water.

Student research projects often utilize the available instrumentation along with one or two other sensor systems that are brought to the field site. The students demonstrate and explain the measurements and sensor operation to each other in the context of their observational objectives. As often happens during field programs, difficulties with sensors and recording systems arise and team discussion helps to find a solution. Equipment parts and software fixes have been shared between the researchers working on previously unconnected activities.

4. A MOUNTAIN ENVIRONMENT PROMOTES INTEGRATIVE SCIENCE

The scientific objectives of the various research projects in the field course have one common objective -- to examine connections between processes occurring at the mountain-atmosphere interface (Borys *et al*., 2000). Topics for the course taught in 2002 took this objective in three primary directions: (a) connections between air chemistry and snow chemistry, (b) connections between pollutant transport in clear-air and cloud environments, and (c) connections between radiative and mass balance components in the mountain environment. The students came from four degree programs (UNR graduate programs in Atmospheric Sciences, Environmental Health & Chemistry, Hydrologic Sciences, and one student from the University of Nevada, Las Vegas graduate program in Chemistry), but the integrative approach of the field class allowed them to produce new knowledge base.

Two complementary projects investigated the causes and effects of aerosol scattering at high altitude, using aerosol sampling, an aethalometer and a nephelometer to characterize temporal patterns in aerosol light extinction due to diurnal inversion cycles at the high-altitude study location, while measurements of actinic UV flux provided new information on the UV scattering and photochemistry associated with ambient aerosol and atmospheric conditions in the high-altitude location. A project on emissions of semi-volatile organic compounds from snowmobiles provided a time series of contaminant concentrations as the compounds entered the snowpack and were transformed by photochemical reactions.

Another study compared the concentrations of water-soluble organic pollutants from sources such as cooking (grilling) and other combustion sources, as found in clear-air aerosol and in cloud water. This research has helped to quantify the process of organic pollutant transport, collection by cloud, and deposition by precipitation or by cloud-to-surface contact (occult deposition) such as fog or riming. A student research project on the spatial representativeness of automated snow measurements documented the accuracy we can expect for snowpack water column mass in different mountain slope locations, which will be used for intercomparisons with NASA remote sensing studies.

Related to this was a project to contrast the radiative budget for forested canopy and open canopy settings above a mountain snowpack, to provide validation data for snowmelt runoff models. The simultaneous activities for each of these investigations, and the teamwork on daily planning and problem solving that took place, produced a rich learning environment and gave the students confidence in their abilities to conduct independent research programs.

Fig. 5. Sampling site for the snow-mobile emissions study of ATMS graduate student Mark McDaniel.

5. BENEFITS AND OPPORTUNITIES

The graduate students from multiple scientific disciplines who participated in this course had high success in completing and presenting their research results. During and following the course, the students expressed their approval of the course format and outcomes. Some of the research papers created from their class projects are in preparation for publication. The research projects developed for the course have led students to extend their research and educational focus in the direction of the interdisciplinary projects conducted during the class. For example, one student is now orienting a component of her research in the direction of orographic cloud chemistry, and she attended an international colloquium on Mountain Meteorology toward this end. Another student is writing grant proposals to allow him to pursue his new research interests in snow chemistry.

Fig. 6. ATMS 792 class photo during one of the snow events that graced the January 2002 field class.

This UNR Atmospheric Sciences course is open to graduate students from other universities, and graduate-level credit can be earned for participation in the course. The involvement of faculty from other universities in the course is welcomed. The DRI Storm Peak Laboratory (www.stormpeak.dri) is also available for use by any college or university with a degree program in Atmospheric Sciences or related discipline to conduct their own field courses. In these cases, DRI provides assistance with instrument training, scheduling and logistics. For more information, please contact the Director of Storm Peak Laboratory, Dr. Randy Borys (borys@dri.edu) or the lead author of this paper (wetzel@dri.edu).

Acknowledgements

This graduate field course is supported by the University of Nevada, Reno and the Desert Research Institute. Instrument acquistion and concurrent research at Storm Peak Laboratory was also facilitated by NSF MRI Grant ATM-0079486, NSF research grant ATM-0004265 and UCAR/COMET grant S02-38657. Support for the mult-channel shadowband radiometer system is provided by USDA. The authors extend their appreciation to the participants of the January 2002 UNR ATMS 792 field course: Tim Bardsley, Arsineh Hecobian, Dong-Chul Kim, Amanda McDaniel, Mark McDaniel, Lynn Rinehart and Katrina Smolen. The Steamboat Ski and Resort Corporation provides continuing cooperation, support and assistance to the research and educational programs at the Storm Peak Laboratory. The SPL facility is a permittee of the Medicine-Bow Routt National Forests.

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